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FLIGHT MEASUREMENTS OF THE ELEVATOR DEFLECTIONS USED IN LANDINGS OF SEVERAL AIRPLANES

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SUMMARY

A collection of data on the elevator deflections used in landings of several airplanes is presented in tabular form. The physical characteristics of these airplanes are also given. The elevator deflection used in landing some airplanes was found to be as much as 14.4° greater than that used to stall under the same flight and loading conditions.

INTRODUCTION

The purpose of this report is to present flight-test data on the elevator deflections used in landing for a number of airplanes. Such information is not available in published form at the present time.

The elevator deflection required to land an airplane is of interest to designers, since the up-elevator deflection range is likely to be determined by the landing condition. Further, if it should be desired to decrease the elevator hinge moments by use of narrow-chord elevators, due consideration must be given the elevator deflection needed for landing. The problem is also of interest when an attempt is made to limit the up-elevator travel of an airplane so that it cannot be stalled in flight but will still be capable of making a good landing.

Wind-tunnel investigations made on the effect of ground interference on trim (references 1 and 2) indicate that when flaps are used large increases in up-elevator deflections may be required near the ground as compared to those at altitude in order to attain a given high angle of attack. These observations are verified in the data contained in this report.

The limited nature of the data available did not permit a complete investigation of ground interference on trim. It is fully appreciated that the value of C_L for

stall at altitude and at landing is probably not the same. However, the comparison of the elevator deflections between stalls at altitude and landings under the same loading conditions is made. The designer should be able to determine from tunnel tests or calculations the elevator deflection required to stall at altitude.

APPARATUS AND TESTS

The data were collected from photographic records taken in tests of the stalling characteristics and landings of the airplanes where the stalls and landings were made under comparable conditions. The records were obtained by installations of NACA recording instruments and a synchronized phototheodolite. The elevator deflections used in landing were determined by correlating the elevator control-position record with the normal acceleration record which shows a marked change at ground contact. Elevator deflections for landings were taken from the record an instant before contact.

Physical characteristics of the airplanes for which data were available are given in table I, and line drawings showing their general arrangement are shown in figure 1.

RESULTS AND DISCUSSION

Table II contains the data for airplanes 1 through 9. This table includes the flap setting, the elevator deflection just before ground contact, the vertical velocity just before contact, the normal acceleration an instant before contact, the maximum normal acceleration at contact, the attitude of the thrust axis at contact, the elevator deflection required to produce an unaccelerated stall at altitude, the indicated air speed to stall at altitude, and the pilot's remarks on the landing.

A summary of the material in table II is given in table III, where the average elevator deflection to make a three-point landing, the elevator angle to stall at altitude, and the difference between the elevator deflection for these conditions are shown. Pertinent data on a number of airplanes not included in table II are also given in table III.

It will be noted from table III that usually, when flaps are used, the difference between the average elevator deflection to make a three-point landing and the elevator deflection to stall at altitude ($\Delta\delta_e$) is quite large; for airplane 2, with 60° flap deflection, $\Delta\delta_e$ is 14.4°.

An attempt was made to correlate the data by reducing $\Delta\delta_e$ to an equivalent change in angle of attack of the horizontal tail surface, but due to the large number of indeterminate factors involved, no consistent results for all the airplanes could be obtained.

An important element that contributes to the magnitude of $\Delta\delta_e$ is the piloting technique employed in the execution of a landing. For example, if a landing approach is made just above the stalling speed in a heavily flapped airplane, it may be impossible to pitch to a three-point attitude and reduce the vertical velocity to zero even by the use of full up elevator, whereas, if the pilot keeps an appreciable margin of speed above stalling, it usually is found that the same airplane can be landed in a three-point attitude with no difficulty. Or, if the airplane is stalled a few feet above the ground, full up elevator is of no avail in attempting to produce a good landing; whereas, if the same airplane is stalled almost in contact with the ground, the elevator travel may be quite sufficient for a good landing. Landing in gusty air conditions also may demand large up-elevator deflections.

Until a more comprehensive investigation of ground effect on trim is made, it is hoped that the data contained herein will be helpful in the design of new airplanes.

CONCLUSIONS

The elevator deflections used in landings of some airplanes are considerably larger than the elevator deflection required to stall at altitude. The maximum value of this difference in the elevator angle required to stall at altitude and to make a three-point landing of the airplanes investigated was 14.4° under the same flight and loading conditions.

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REFERENCES

1. Lyon, H. M., and Adamson, J. E.: The Effect of Ground Interference on Trim of a Low Wing Monoplane. R. and M. No. 1861, British A.R.C., 1938.

2. Sears, William R.: Ground Effect with Special Reference to Pitching Moments. Jour. Aero. Sci., vol. 5, no. 7, May 1938, pp. 281-285.

TABLE III

Summary of Landing Data

Airplane	Flap position (deg)	Average elevator angle to make a three-point landing, (deg) up	Elevator angle to stall at altitude, (deg) up	$\Delta\delta_e$, (deg)
1	25	18.9	8.0	10.9
2	0	8.2	6.5	1.7
2	30	11.3	4.5	6.8
2	60	19.8	5.4	14.4
3	59	13.2	10.0	3.2
5	45	22.2	12.0	10.2
6	0	24.1	16.0	8.1
6	31	23.6	16.0	7.6
7	0	20.9	22.7	-1.8
8	0	17.4	21.0	-3.6
9	0	13.0	17.0	-4.0
10	0	15.0	11.0	4.0
10	30	17.0	12.5	4.5
11	45	22.0	10.4	11.6
12	60	21.0	9.2	11.8
13	50	17.8	8.0	9.8
14	67	21.7	23.0	-1.3
15	45	16.0	12.5	3.5

TABLE I

PHYSICAL CHARACTERISTICS

OF AIRPLANES TESTED

Air-plane	Wing area, (sq ft)	Wing span, (ft)	Aspect ratio of wing	Taper ratio of wing	Hori-zon-tal tail area, (sq ft)	Hori-zon-tal tail span, (ft)	Aspect ratio of tail	Elevator area / Total tail area	Type of flap	Flap area, (sq ft)	Center-of-gravity posi-tion, (per-cent M.A.C.)
1	2780	149	8.0	4.3	505	45.0	4.0	0.36	Split	256	25.9
2	1420	104	7.6	2.7	254	33.8	4.5	.37	Split	109	29.1
3	965	89.5	8.4	2.8	203	26.7	3.5	.30	Split	63	22.0
4	545	65.5	7.9	3.5	116	21.7	4.1	.34	Fowler	93	30.2
5	236	37	5.9	2.5	48	12.8	3.4	.33	Split	35	26.7
6	155	34	7.5	1.0	28	9.3	3.1	.39	Plain	12	29.0
7	169	36	7.7	1.0	25	10.2	4.1	.46	None	---	28.1
8	180	36	7.2	1.0	26	10.0	3.9	.42	None	---	25.1
9	162	34	7.2	2.0	25	10.8	4.7	.38	None	---	22.0
10	134	30	6.8	1.0	24	8.7	3.7	.41	Plain	11	22.0
11	236	37.5	5.9	2.5	48	12.8	3.4	.36	Split	35	23.6
12	224	36	5.8	Elip.	51	13.8	3.7	.36	Split	28	28.5
13	314	41	5.3	1.5	59	16.5	4.6	.38	Slotted	41.7	27.1
14	258	39	5.4	1.5	61	14.9	3.6	.50	Split	20.4	25.5
15	260	38	5.6	1.6	49	13.7	3.8	.38	Split	29.7	28.5

Air-plane	Mean aero-dynamic chord, (ft)	Height at wing quarter-chord point above ground in three-point atti-tude, (ft)	Height eleva-tor hinge above ground in three-point atti-tude, (ft)	Ground angle of thrust axis, (deg)	Up-eleva-tor travel avail-able, (deg)	Gross weight, (lb)	Angle of inci-dence of wing, (deg)	Wing section	
								Root	Tip
								NACA:	NACA:
1	21.3	8.5	4.5	7.7	26	48,100	4.5	0018	0010
2	14.8	7	3.0	7.5	29	39,000	3.5	0018	0010
3	11.7	6.5	4.5	10.5	28	20,400	2	2215	07.6
4	9.2	5.5	4.0	14.0	34	14,700	2	23018	23009
5	6.8	4	3.0	14.3	28	5,780	1	2215	2209
6	4.8	6	1.4	12.0	26	1,385	---	4412	4412
7	4.8	6	1.8	13.5	34	1,090	$-1\frac{1}{2}$	Clark Y	
								NACA:	
8	5.0	6.	2.0	9.0	27	1,060	---	23012	23012
9	5.0	3	2.3	12.0	23	1,503	---	---	---
10	4.4	3	1.8	12.6	30	1,530	3	2412	2412
11	6.8	4	3.0	14.3	29	6,380	1	2215	2209
12	6.2	4.5	2.0	14.5	30	6,500	1	---	---
13	7.8	5.3	2.7	14.9	21.5	9,280	2	23018	23009
14	7.0	5.5	2.2	10.0	30	5,690	0	NACA-CYH	NACA-CYH
15	7.0	5.5	4.0	10.0	25	6,600	0	---	---

TABLE II

LANDING DATA FOR AIRPLANES 1 TO 9

Landing	Flap position, (deg)	Elevator angle just before contact, (deg) up	Vertical velocity instant before contact, (fps)	Normal acceleration instant before contact, (g)	Maximum normal acceleration at contact, (g)	Attitude of thrust axis at contact, (deg)	Elevator angle to stall at altitude, (deg) up	Indicated airspeed at stall at altitude, mph	Type of landing and remarks
				AIRPLANE 1					
1	0	12.8	0.9	1.03	1.35	7.2	--	--	Tail first, partial power
2	0	16.3	2.6	.96	1.60	7.9	--	--	Tail first, partial power
3	25	--	2.1	.98	1.32	6.9	8.0	54	Three point, partial power
4	25	19.0	2.1	1.00	1.39	7.6	8.0	54	Three point, mild partial power
5	25	18.5	--	1.03	--	8.1	8.0	54	Wheels first, partial power
6	28	19.2	1.9	1.01	1.53	7.5	8.0	54	Three point mild, partial power
7	26	18.7	2.6	1.00	1.35	7.5	8.0	54	Three point mild, partial power
8	27	18.5	2.1	1.03	1.35	8.1	8.0	54	Three point mild, partial power
9	60	17.5	3.7	1.00	1.60	3.6	17.5	59	Wheels first, bounced, partial power in approach, power cut just before contact
10	60	16.5	2.5	1.07	1.64	3.2	17.5	59	
				AIRPLANE 2					
				(All three-point landings)					
1	0	8.0	2.7	--	1.45	7.5	6.5	86	
2	0	8.4	1.2	1.00	1.33	8.1	6.5	86	
3	30	11.3	4.4	--	1.48	8.1	4.5	--	
4	45	14.5	4.1	1.12	1.29	7.9	--	--	
5	60	18.2	2.1	1.11	1.47	8.7	5.4	73	
6	60	21.1	--	--	--	--	5.4	73	
7	60	20.1	--	--	--	--	5.4	73	
				AIRPLANE 3					
1	0	12.2	3.3	0.98	1.53	12.5	--	--	Tail first
2	59	12.6	3.1	1.00	1.12	11.0	10.0	70	Three point
3	59	14.3	2.9	.90	1.09	11.5	10.0	70	Three point
4	59	--	--	.95	--	--	10.0	70	Three point
5	59	12.6	6.0	.90	1.40	8.7	10.0	70	-----------
6	59	18.6	4.3	.63	--	11.7	10.0	70	Tail first
7	59	8.5	4.8	.95	1.33	10.3	10.0	70	Wheels first
8	59	--	3.2	--	--	6.1	10.0	70	Wheels first
				AIRPLANE 4					
1	0%[a]	19.4	1.9	1.00	1.41	14.9	--	--	Tail first
2	20%[a]	21.0	1.0	--	--	--	--	--	Almost three point, power drag in
3	20%[a]	14.0	1.6	--	--	--	--	--	Wheels first bounced
4	75%[a]	14.3	.3	1.02	1.20	9.1	--	--	Wheels first bounced
5	100%[a]	23.0	1.0	1.00	1.22	10.6	--	--	Wheels first bounced
				AIRPLANE 5					
1	30	22.2	--	--	--	--	--	--	Three point
2	30	22.0	2.6	0.93	2.02	12.3	--	--	Slightly tail first
3	30	21.0	1.6	1.00	1.61	12.6	--	--	Normal three point
4	32	19.8	1.4	1.00	1.40	12.0	--	--	Slightly tail first
5	45	14.8	2.2	1.08	1.79	11.0	12.0	66	Flared wheels first bounced
6	45	22.3	2.8	1.05	2.28	13.4	12.0	66	Three point (held off)
7	45	23.3	1.6	1.00	1.65	11.3	12.0	66	Steady tail first
8	45	22.2	1.2	.95	1.43	11.7	12.0	66	Short burst power, steady three point
9	45	24.0	1.8	1.00	1.58	11.2	12.0	66	Power approach, wheels first bounced
10	45	18.7	1.7	1.00	1.47	11.3	12.0	66	Floater, three point
11	45	24.4	1.9	1.00	1.54	11.0	12.0	66	Power drag in, smooth tail first
12	45	18.0	4.6	1.00	2.08	11.0	12.0	66	Wheels first bounced
13	45	22.6	2.3	.94	1.63	10.9	12.0	66	Smooth three point
14	45	21.8	.9	.98	1.32	12.1	12.0	66	Three point
15	45	28.0	2.7	.99	1.61	14.3	12.0	66	Mild tail first
16	45	25.7	3.6	.95	1.92	12.8	12.0	66	Three point slight power
17	45	28.0	2.3	.84	1.88	13.1	12.0	66	Tail first slight power

TABLE II (CONTINUED)

LANDING DATA FOR AIRPLANES 1 TO 9

Landing	Flap position[a] (deg)	Elevator angle just before contact, (deg) up	Vertical velocity instant before contact, (fps)	Normal acceleration instant before contact, (g)	Maximum normal acceleration at contact, (g)	Attitude of thrust axis at contact, (deg)	Elevator angle to stall at altitude, (deg) up	Indicated airspeed at stall at altitude, mph	Type of landing and remarks
AIRPLANE 6									
1	0	24.1	1.6	0.90	1.75	12.2	16.0	48	Mild three point
2	0	25.3	3.6	.90	1.80	12.8	16.0	48	Tail first partial power
3	0	25.3	9.5	.80	4.00	13.2	16.0	48	Dropped 3 ft partial power
4	0	24.1	9.5	.72	4.63	9.0	16.0	48	Wheels first bounced
5	0	4.8	4.8	.93	2.53	2.8	16.0	48	Wheels first bounced
6	0	7.7	1.6	.95	1.30	4.4	16.0	48	Power on, wheels first tangential
7	0	6.5	1.3	.97	1.15	7.6	16.0	48	Power on, left wheel tangential
8	0	11.7	1.3	.96	1.18	8.3	16.0	48	Power on, right wheel tangential
9	0	25.3	6.0	--	--	12.2	16.0	48	High level off, hard on left wheel
10	31	23.6	.9	.93	1.34	11.7	16.0	44	Three point mild
11	31	25.3	5.6	.77	2.92	11.2	16.0	44	Dropped in partial power
12	31	6.0	4.8	.03	2.67	1.3	16.0	44	Wheels first bounced
13	31	25.3	9.1	.77	4.35	7.0	16.0	44	Dropped in 5 ft
14	31	10.5	1.4	.96	1.30	10.9	16.0	44	Normal on left wheel
AIRPLANE 7									
1	None provided	[illegible]	0.8	1.00	1.61	10.4	22.7	43	Three point
2		[illegible]	1.5	.98	1.47	9.6	22.7	43	Three point
3		17.0	--	1.08	1.44	--	22.7	43	Three point, perfect
4		25.6	[illegible].5	1.02	2.06	11.6	22.7	43	Full flare to three point
5		10.8	4.[illegible]	.99	2.58	4.5	22.7	43	Wheels first bounced
6		4.0	--	.84	1.61	--	22.7	43	Wheels first bounced
7		14.9	5.4	1.09	2.01	7.3	22.7	43	Unchecked glide
8		19.5	--	1.08	1.70	--	22.7	43	Left wheel
9		30.3	4.8	.90	2.17	10.5	22.7	43	Dropped 3 ft, three point
10		32.0	7.4	.65	3.18	--	22.7	43	Dropped 5 ft
11		32.9	--	.91	1.96	--	22.7	43	Tail first
AIRPLANE 8									
1	None provided	17.4	0.7	0.94	1.28	9.1	21.0	38	Perfect three point
2		21.2	1.5	.98	1.79	7.2	21.0	38	Held off, dropped in
3		24.8	4.3	.85	2.68	7.5	21.0	38	Held off, dropped in
4		2.1	4.2	1.00	2.08	.3	21.0	38	Unchecked glide
5		2.4	3.9	1.02	2.25	.2	21.0	38	Unchecked glide
6		27.0	3.2	.64	2.10	13.5	21.0	38	Held off
7		27.0	4.6	.72	2.81	6.4	21.0	38	Held off to stall, dropped in
8		27.0	3.5	.85	2.10	9.3	21.0	38	Tail first
9		-.3	2.4	.89	1.74	-1.3	21.0	38	Unchecked glide
10		10.4	5.0	.98	2.49	2.6	21.0	38	Unchecked glide
11		5.1	1.3	.89	1.70	4.7	21.0	38	Unchecked glide
12		1.5	1.7	.98	1.49	4.7	21.0	38	On right wheel
13		5.1	.8	.94	1.53	4.3	21.0	38	On left wheel
14		2.1	2.3	.98	1.45	4.0	21.0	38	On right wheel
15		4.6	3.3	.98	2.25	1.8	21.0	38	Unchecked glide partial power
16		3.9	3.1	.98	1.70	2.2	21.0	38	Unchecked glide partial power
AIRPLANE 9									
1	None provided	13.0	0.7	1.03	1.30	10.9	17.0	52	Three point dropped in
2		13.0	2.0	1.05	1.11	9.7	17.0	52	Three point
3		7.3	3.3	.99	1.87	5.0	17.0	52	Two point
4		8.3	3.3	.95	1.72	5.5	17.0	52	Two point
5		8.3	8.3	1.11	2.59	3.9	17.0	52	Two point
6		9.3	.9	.97	1.68	8.8	17.0	52	Two point, partial power
7		8.3	3.8	1.03	1.77	5.5	17.0	52	Two point, partial power
8		7.3	3.4	1.18	1.54	5.4	17.0	52	Two point, partial power
9		17.0	1.2	.99	1.11	13.4	17.0	52	Tail first
10		16.5	2.0	1.00	1.18	12.2	17.0	52	Tail first
11		17.0	1.2	1.11	1.17	13.3	17.0	52	Tail first
12		17.0	2.3	1.02	1.28	13.2	17.0	52	Tail first
13		17.0	2.3	.99	1.07	12.3	17.0	52	Tail first
14		17.0	1.6	.93	1.49	12.1	17.0	52	Tail first, partial power

[a]Flap deflections in percentage of full deflection.

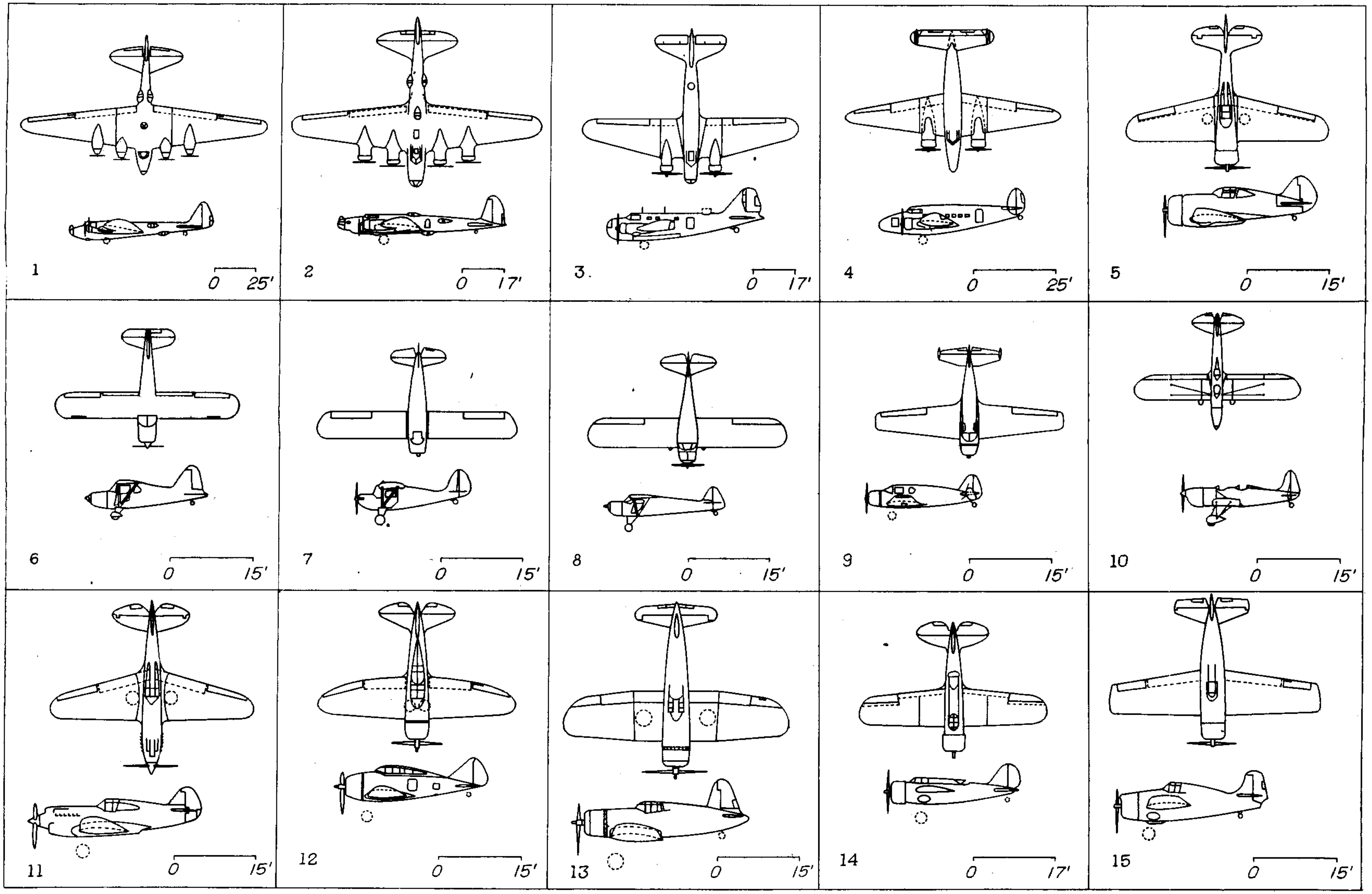

Figure 1.- Line drawings of airplanes tested in flight.